

# A strategy for reviewing the biology of animals

**Graham H. Pyke**

Australian Museum, 6 College St., Sydney, New South Wales 2010,  
grahamp@austmus.gov.au

## ABSTRACT

With the advent of computer-based technology and the increasing need to focus on the biology of plant and animal species, it is both necessary and timely to adopt strategies for reviewing available information concerning individual species. To be most useful, biological reviews should be able to cope with taxonomic uncertainty and change, should be comprehensive with regard to topics, sufficiently detailed, repeatable and easy to keep up-to-date, should include anecdotal observations, and should indicate the nature and extent of support for each statement concerning a species.

I present here a computer-based strategy which I have adopted for carrying out such reviews and illustrate it with the example of the diet of the Green and Golden Bell Frog *Litoria aurea*.

Key words: review, biology, *Litoria aurea*, diet, conservation, management, human impact.

## INTRODUCTION

A knowledge of the biology of animal or plant taxa may be useful or necessary in a number of contexts. These include (see also Janzen 1997):

- predicting impacts of proposed human activities
- planning conservation and/or management
- satisfying interest or curiosity.

In these contexts the taxon of interest may be just one particular species, but interest could also extend to a number of subspecies or to a group of species.

It is not possible to predict the impacts of human activities on animals or plants without a knowledge of the biology of the species involved (Janzen 1997). In order, for example, to predict the impacts of timber harvesting on a particular species, it is necessary to know whether or not it is a species that is dependent on tree hollows. If it is, then it is also necessary to know the relationships between its population density and various factors such as the area of suitable habitat available and the density of old trees with hollows that are retained after logging (e.g., Gibbons & Lindenmayer 1997).

It is also impossible to plan for the conservation and/or management of a species without a knowledge of its ecology and other aspects of its biology (Janzen 1997). In order, for example, to establish a reserve where a species is protected from human disturbance as much as possible and where some areas of habitat are managed so as to maintain the population, it is necessary to know where the species occurs and something about its habitat requirements. For example, at Barren Grounds Nature Reserve (near Jamberoo, New South Wales), which was largely established to conserve populations of the Eastern Bristlebird and Ground Parrot (New South Wales National Parks & Wildlife Service 1996), a fire management plan has been adopted which seeks to ensure that the area receives a fire regime that is compatible with maintenance of these two species (New South Wales National Parks & Wildlife Service 1996).

There is also considerable general interest in natural history and satisfying this requires information about the biology of plant and animal species. Evidence of this is easily found in the large number of available books that deal with natural history. Some species are discussed

along with many other species, as occurs in books such as those by Allen (1989), Tyler (1976), Blakers et al. (1984), Cogger (1992) and Strahan (1995). A few species, such as the Koala, have had entire publications devoted to them (e.g. Cronin 1987; Lunney et al. 1990).

Reviews of the biology of plant and animal species may be extremely valuable as sources of information about individual species. Without such reviews anyone interested in a particular species must either observe the species in person or attempt to access and assimilate available written information concerning the species. Such written information is generally scattered and fragmentary. At present, books such as those described above are the principal source of biological reviews. It is inefficient for a number of people to attempt to review what is essentially the same information base.

A biological review may be based on either the experience of the author or on a compilation of written information concerning the taxa involved, or on both approaches. It is often hard to differentiate between these two approaches as the authors of such reviews are generally people who have had considerable direct experience with the taxa concerned and these reviews generally do not include full accounts of the nature and extent of support for statements made (e.g. Blakers et al. 1984; Allen 1989; Cogger 1992; Strahan 1995).

In this paper I shall focus on biological reviews that are based on written information. It would also be possible to include information based on the experiences of people who have directly observed or detected the taxa involved, but only if such people were able to tabulate their records. Then, of course, the information would be available in written form.

To be most useful, for whatever intended use, biological reviews should:

- cope with taxonomic changes or uncertainty associated with any of the species, subspecies or groups of species reviewed (there may be uncertainty or disagreement concerning the taxonomy of a species or a group of species; presumed species may be considered synonymous and combined; single species may be split into two or more distinct species);
- be comprehensive with regard to topics (identifying both what is not known as well as what is known);
- be sufficiently detailed (with level of detail reflecting level of knowledge for particular species);
- be repeatable (in sense that different reviewers produce similar reviews of the same species);
- easy to keep up-to-date;
- include anecdotal observations (as well as the results of more targeted data recording schemes);
- consider possible variation in "quality" of available information (species identification may, for example, be considered uncertain and might be rated according to a perceived likelihood of correctness, as occurs in the New South Wales National Parks and Wildlife Service (1996) Atlas of New South Wales Wildlife);
- indicate the nature and extent of support for each statement concerning a species (e.g. single observation, summary of a number of observations, reference to someone else's observations, simple assertion).

Anecdotal observations can be useful, especially if tabulated and summarised (e.g. Pyke 1980). An observation, for example, that the Eastern Spinebill *Acanthorhynchus tenuirostris* usually visits someone's garden every spring and is noted to feed at this time from the flowers of a particular plant species, often while hovering, potentially provides considerable information. It provides information about habitat (gardens included), diet (nectar, particular plant species), seasonal movements (among different habitats or regions), and mode of foraging (hovering vs perching). When such information is tabulated and summarised, biological patterns may emerge that would otherwise not be apparent.

In situations where variation in "quality" of available information may affect the outcomes of a review process, this should be noted. This can easily occur in the context of taxon distribution where identification is uncertain (e.g. Farr & Rossman 1997), but it may also affect other kinds of information.

With regard to the nature and extent of support for statements that have been made concerning the biology of a particular species (or subspecies or species group), it is also important, as much as possible, to distinguish conclusions based on genuine data from "proof by assertion" where a statement, once made, is accepted without critical evaluation and from "proof by repetition" where a

statement becomes accepted by virtue of having been repeated a number of times. Such "proofs" serve to undermine the review process and any decisions or actions that follow from a review.

Any system for carrying out biological reviews must be able to cope with large numbers of documents and potentially large numbers of species and subspecies, spanning many taxonomic groups. For example, for commonly encountered species such as the Eastern Spinebill, the number of published articles that provide information about the species exceeds 500. In Australia there are about 656 bird species, 250 mammals, 467 reptiles, 195 frogs and 181 freshwater fish, plus many thousands of species of plants, marine fish, invertebrates and other organisms. In principle, reviews might someday be required for any or all of these species and some separate subspecies. Fortunately, modern computer technology makes this possible (e.g., Farr & Rossman 1997; Janzen 1997; see below).

Any such system must therefore be able to cope with very large amounts of information. Given the potentially large number of topics for each taxon (see below) and the sometimes large number of relevant documents, it is no trivial task to collate, analyse and summarise all the available information for a particular taxon. This task is made even larger when the potentially high number of taxa is taken into account. This task is, furthermore, increasing in size all the time as more observations are documented. Modern computer technology also makes it possible to handle such a volume of information (see below).

The aim of the present paper is to present and illustrate a system that I have developed for carrying out biological reviews. I have attempted to develop a system with the above desirable properties and with the ability to cope with potentially large numbers of documents and taxa, as well as large and growing amounts of information. Of course, there is a very large number of biological reviews that are already published and any strategy for preparing reviews, such as that proposed here, could be viewed as relatively idiosyncratic. Furthermore, many review authors are likely to use some or all of the approaches I advocate here. There are, however, no apparent published descriptions or discussions of the processes used to prepare and revise such reviews. It is in this context that I have prepared this paper.

In the following discussion I shall focus primarily on animals rather than plants. My system could, however, be easily adapted to deal with plants.

## BIOLOGICAL REVIEW SYSTEM

### General Description

My biological review system involves the following four related approaches - Taxonomic Scope, Document Set, Topics List and Bibliographic Database. I shall discuss each of these in turn.

The Taxonomic Scope is a list of species and subspecies that will be included in the review and differentiated between in terms of biological information. The first step in determining such a list is to adopt a taxonomy for the species or species group under consideration. This is reasonably easy if there is only one generally accepted taxonomy, but is more difficult if there is no established taxonomy or if there are conflicting views. In any case a decision has to be made. When collating biological information the species or subspecies involved can be noted, but in order to summarize this information it is necessary to decide which species or subspecies will be differentiated. This will generally depend on the level of information available for each species or subspecies. If the amount of available information allows comparison between species or subspecies then the results of these comparisons should be included in the summary. If available information is relatively scant or there are no apparent differences, then species or subspecies may be combined.

This Taxonomic Scope approach will cope with the most likely future changes in taxonomy. If subspecies are elevated to species, then a species review with comparisons between subspecies may become a review of a group of species. If species are combined then a review of two or more species may become a review of a single species or a species review may become a subspecies review. Of course taxonomic changes can be imagined that would warrant major revision to a review of a species or group of species.

The Document Set is the set of documents that are considered likely to contain information relevant to the particular species, subspecies or group of species under review. I have compiled these Document Sets by a combination of:

- searching likely journals, books and other documents for articles with titles that suggest they may contain relevant information
- using prepared species-based indices of journals where they exist
- following the trail of citations from one document to another

In my experience no single one of these approaches is very effective and it is necessary to employ the combination in order to be confident of locating a reasonably high proportion of the relevant documents that exist. There is often a relatively closed group of documents that refer to each other but not to documents outside the group. Just searching likely journals leads to relevant articles in the less likely places being missed. Species-based indices are available for a limited number of journals, but sometimes do not apparently cover the entire publication history of the journal. In the case, for example, of the journal *Emu*, I have been unable to find species indices for volumes 75, 78 and 81. Of course, no approach or combination of approaches can guarantee location of all relevant documents.

I have attempted to include, as much as possible, the "grey" literature in these Document Sets, as they often contain useful information. For example, documents such as Environmental Impact Statements and Species Impact Statements, which generally seek to describe the likely impacts of proposed human activities on the natural environment, often include brief biological reviews for certain animal and/or plant species and may also include observations of these species that have been made during biological surveys of the relevant area. Pursuing such documents is often, however, a difficult task as there is no standard procedure for depositing copies of them in a library.

The Topics List for a particular species, subspecies or species group is chosen to be:

- hierarchical (i.e., most general topics first, each of which may be subdivided into more specific topics, which may be further subdivided, and so on);
- comprehensive (i.e., any biological information about a species should fit in somewhere);
- easily expanded (i.e., should easily accommodate addition of new items in the topics list);
- applicable, as much as possible, to other species within a broad group or category (e.g., the topics list for a particular bird species may largely apply to any other bird species).

The first, and most general level in the Topics List hierarchy includes species, research techniques, individual, population, community

and miscellaneous. Under each of these topics there is then a second level in the hierarchy. Under 'species', for example, are included the features that identify and distinguish the particular species (description), topics that deal with the relationships of the particular species to other species (phylogeny, evolution) and topics that consider whether the review is dealing with one or more than one species (geographic variation, subspecies).

It is hoped that the first two hierarchical levels in this Topics List will be able to deal with any animal species. It would be easy, however, to add further topics to this list at either of the two levels.

At the third level in the hierarchy differences will start to appear between different animal groups. Topics under growth and development will differ, for example, between birds and most mammals since birds lay and incubate eggs while most mammals give birth to partially developed young. Hence 'incubation period' is a topic for birds but not most mammals, whereas the reverse is true for 'gestation period'.

As each level 2 topic may give rise, in turn, to several topics at level 3 the total number of potential level 3 topics is very large. The topics under 'reproduction' for a bird species would, for example, include clutch size, location of eggs and seasonal pattern.

I have found that the third level topics in the Topics List hierarchy can generally be applied to all species within an animal Class (i.e. to all birds or all frogs etc.).

The forth part of my biological review system consists of a computer-based Bibliographic Database which is able to:

- store standard citation information associated with each document;
- store written account or summary of relevant content of each document;
- record keywords or key phrases that reflect the topics covered in each document;
- store potentially large amounts of information associated with each document;
- locate and group documents on the basis of author, keyword etc;
- transfer citation information and document accounts or summaries to wordprocessing software.

I have developed this Bibliographic Database using the computer software Papyrus (Research Software Design 1998). This software allows entry of bibliographic information using fields for standard citation information such as author, year, journal etc. plus fields for keywords or key phrases (maximum 80) and a field for "comments" which I use for summarising the document (maximum 8000 characters). This software also has various search and group options which allow information to be retrieved as required and transferred to wordprocessing software. There are other software packages that will perform similar operations.

When summarising each document I use numbered sentences (or equivalent) and attempt to include information that is relevant to just one of the adopted topics in the topics-list-hierarchy in each sentence. During the initial development of this system, this process occasionally prompted the addition of a topic to the Topics List (see below for example). However, now it rarely does.

Summarising each document is a somewhat subjective exercise. I have found, however, that when different people follow the same format and have the same topics in mind, the end results are reasonably similar. Summarising each document is a crucial step in the overall process of carrying out a biological review.

#### **Adequacy of Document Set, Topics List and Bibliographic Database**

Since none of the Document Set, Topics List or Bibliographic Database can ever be considered complete, the processes of formulating them could potentially continue indefinitely. A stopping rule is therefore required for deciding when these components of the system are sufficiently advanced for the review to be prepared.

I propose that these processes stop when the pursuit of an essentially new direction to locating relevant documents (e.g., searching references to a particular species in a new journal) contributes fewer than 1% new documents to the Document Set. With such a stopping rule the review system becomes essentially finite. However, any relevant documents that are discovered at a later time can be easily incorporated into the review.

#### **Preparing initial reviews**

The initial biological review is based on the Topics List and the Bibliographic Database. It is prepared in the following stepwise manner:

1. Bibliographic Database is searched using species and topic keywords (using inbuilt functions of Papyrus) for all relevant documents
2. A text file is created which includes the standard citation information followed by the prepared summaries for all relevant documents
3. The biological information in this file, along with the associated citation information, is rearranged by topic in the Topics List.
4. Within each topic, the biological information is sorted by subspecies and/or species, depending on the adopted Taxonomic Scope and the comparisons that seem reasonable to make.
5. The information for each topic and, if appropriate, each species and/or subspecies is tabulated if necessary.
6. The information for each topic is summarised with the inclusion of any appropriate comparisons between subspecies or species.

These summaries plus any necessary citations become the biological review (see below for example). Of course, if a Review is wanted with regard to just a subset of possible topics, then the above processes focus on just the desired topics. In this way, for example, a Review might be prepared which deals with just the foraging behaviour of a particular species.

When a biological review is being carried out for a particular species, subspecies or group of species (as in the present situation) the computer-based search of the Bibliographic Database (i.e., Step 1 above) is relatively simple and requires only that Papyrus locate and group all documents with a keyword equal to one of the taxon names included in the adopted Taxonomic Scope. Papyrus is then able to output a text file that includes the summaries of all the documents in this group plus the citation details for each document and is compatible with a number of commonly-used wordprocessing software packages. I refer to this file as the Basic Information File.

Using my wordprocessing software, I then rearrange the information in this file in the following stepwise manner.

1. Create new file which initially contains just the list of topics as per the adopted Topics List;
2. Copy and/or move the information in the Basic Information File, one sentence at a time,

to appear under any relevant topic headings and append the appropriate citation information to it (in cases where a sentence in the Basic Information File relates to two or more topics it is moved to one of these topic headings and copied to the others).

As this process continues the Basic Information File shrinks and eventually disappears, while the other file grows in size. I refer to this second file as the Sorted Information File. It is easy to recreate the Basic Information File if it is needed at a later time.

Tabulation of the information in the Sorted Information File is sometimes the next step in the review process, especially when the sorted information under one or more of the topic headings contains a large number of anecdotal observations. A good example of this would be the large number of anecdotal dietary feeding observations of a commonly encountered honeyeater species. Such observations would appear in the Sorted Information File for that species under the third level heading of foraging and a fourth level heading of diet. An indication of the overall diet of the species can be obtained in this situation by tabulating all the observations in terms of several dietary categories such as nectar, insects and fruit (e.g. Pyke 1980). As such anecdotes constitute most or all of the information that is available under some topic headings for some species, their compilation, sorting and tabulating can make a significant contribution to our biological review.

The final step in the process of preparing a biological review is the summarising of the information in the Sorted Information File. This I do as a numbered sequence of points with summaries of supporting evidence under each topic heading, at times taking care to distinguish recorded observations from assertions, especially when these would lead to different conclusions. These points are generally relatively simple ones, such as "The average clutch size has been observed to be x". Sometimes, however, the point may be a slightly more complex one, such as "The average clutch size has been observed to decrease through the species' range from about y in the south to z in the north". To make this document more readable I then created a sequence of paragraphs by removing point numbers and combining related points where appropriate. The resulting overall sequence of paragraphs, grouped by topic heading, becomes the biological review. At the end of these summaries I sometimes include a list of studies that

have apparently not been carried out, especially where such studies are clearly needed. These summaries include appropriate citations.

At the same time a standard bibliography is prepared with the appropriate information for each document cited in the summary.

### Updating reviews

This Biological Review System is relatively easy to update when an additional relevant document becomes available. The new document is first added to the Bibliographic Database and its summary added to the Basic Information File. The information in this summary is then copied and/or moved to the relevant topic headings of the Sorted Information File, where it is added to any tabulations if necessary and compared with the current summaries of the Sorted Information for these headings. The summaries may be modified in light of the new information, but this is often unnecessary.

### Example

As an example of the application of this Review System I shall consider the "natural adult diet" of the endangered Green and Golden Bell Frog *Litoria aurea* (as opposed to what this species eats in captivity). This will form part of a full Biological Review that is presently being undertaken by the author and A.W.White.

I have so far located and summarised a total of 11 documents that provide information in relation to the diet of adults of this frog species in the wild (see Appendix 1). These documents constitute the Document Set for the present paper. They have been entered and summarised into Papyrus as described above.

Using Papyrus, a Basic Information File is created for this Document Set. When all material in this Information File is removed except for material that is relevant to the diets of adult *L. aurea* in the wild, a modified Basic Information File is produced. This new file constitutes the Basic Information File for the present paper. It is presented in Appendix 1.

Some of the material in this adopted Basic Information File is tabulated before being summarised. In this case, the Basic Information File contains a reasonably large number of statements concerning the wild diets of adult *L. aurea* (Appendix 1). Their tabulation facilitates any appropriate generalisations (see Table 1 & Appendix 1).

Finally, the material in the Basic Information File and the Associated Tabulation is summarised

(see Appendix 2). In this case a list is included of studies that are clearly needed. This summary constitutes the Biological Review for the diet of adult *L. aurea* in the wild.

This Biological Review will be relatively easy to update when another relevant document is added to the Document Set. Inclusion of such a document in the Bibliographic Database and Basic Information File is straightforward, following the same procedures as explained and illustrated above. If appropriate, material from this new document is also added to the tabulation and, if necessary, the final summary is modified.

## DISCUSSION

This Biological Review System that I have developed seems reasonably straightforward to adopt and implement in any situation where it is necessary to compile and review available information. It can obviously be somewhat tedious at times and this, plus its rather regimented approach, may not appeal to everyone. However, in the present so-called "information age", where computer technology permits the processing of large amounts of information, the extent of biological and other kinds of information is growing constantly (and at times rapidly). There is an increasing need for good summaries or reviews of available information, and an urgent need for the development and adoption of a standardised system for compiling and reviewing available information (Farr & Rossman 1997; Janzen

1997). I present my system as a candidate for such a standardised system.

It is premature to assess how well my Biological Review Strategy will achieve the above list of desirable qualities, but early signs seem promising. As the list of adopted topics is developed, new topics are added at an ever decreasing rate and eventually cease altogether, and so the final topics list is likely to be quite comprehensive. The end result in two reviews in preparation (one on the Hastings River Mouse *Pseudomys oralis* and one on the Green and Golden Bell Frog *Litoria aurea*) are relatively large documents of about 60 single-spaced A4 pages each. While reviewing information for a number of honeyeater species, it has been my experience that different people, if trained appropriately, will produce similar results, which suggests that the system is repeatable. However, this particular aspect of my strategy warrants further consideration as the end result can easily depend on many factors including subjective judgements about the scope of the search, the diligence of the bibliographers, their prior knowledge of the literature and their ability to access key sources. As explained above, new references are easy to incorporate into the process and hence the system, with appropriate effort, is easy to keep up-to-date. As illustrated by the present example of the diet of the Green and Golden Bell Frog and by an earlier review of the behaviour of honeyeaters (Pyke 1980), anecdotal observations are potentially useful sources of information in the review process.

Table 1. Tabulation of statements concerning diet of adult *Litoria aurea* in the wild (based on Appendix 1)

Dietary item or description	Number of references	References
Same species	3	Barker & Grigg 1977; Frog and Tadpole Study Group unpublished; Hoser 1989
Other frog species	7	Barker & Grigg 1977; Coupe 1993; Frog and Tadpole Study Group unpublished; Hero et al. 1991; Krefft 1863; State Forests of New South Wales 1993; White 1993
Lizards	1	Coupe 1993
Small snakes	1	Krefft 1863
Grasshoppers	1	Frog and Tadpole Study Group unpublished
Crickets	1	Frog and Tadpole Study Group unpublished
Cockroaches	2	Frog and Tadpole Study Group unpublished; Krefft 1863
Slugs & worms	1	Lucas & Le Souef 1909
Ants, beetles & centipedes	1	State Forests of New South Wales 1993
Flies & mosquitoes	1	Lucas & Le Souef 1909
General carnivore	3	Cogger et al. 1993; Krefft 1863; State Forests of New South Wales 1993

An example of how my Biological Review Strategy copes with changing taxonomy is provided by the example of two fish species, *Gambusia affinis* and *G. holbrooki*. There has been considerable interest in these two species for about 100 years, largely because of their prominent role in the control of mosquitoes throughout the world, and I presently have over 900 references for one or other of them. For most of this time these two species were considered subspecies of *G. affinis* rather than separate species, it is sometimes difficult or impossible to determine which species was actually considered in some studies, and the species are extremely similar in all aspects of their biology. For these reasons I am in the process of reviewing them as a species group, making comparisons between them where possible and appropriate.

In my experience variation in "quality" of information has not been a significant issue, except, as the above example illustrates, in cases where taxon identification has changed or been uncertain. In most cases observations, or tabulations of observations or statistical summaries of observations, can be taken at face value and incorporated into the review process. Likewise, expressed opinions can be tabulated and summarised. The final review may therefore contain sentences with beginnings such as "It is generally observed that ....." or "It is generally believed that .....".

Given the vast amounts of biological information available, the undoubtedly huge task of reviewing all this information by adopting my proposed Biological Review Strategy, or indeed any other strategy, and then keeping these reviews up-to-date, may seem like impossible goals. Making the resulting reviews available and accessible to potential users may also seem problematical. It seems to me, however, that it should not necessarily be difficult to solve these problems. I have so far been involved in several biological reviews in accordance with my recommended strategy, thus demonstrating that one person can make a contribution in this area

(e.g. Pyke 1980). There is, however, no obvious scientific journal in which to publish such reviews, since existing journals that publish reviews typically concentrate on topics or issues rather than specific taxa (e.g., Quarterly Review of Biology; Annual Review of Ecology and Systematics) and these journals would probably be unable to cope with the volume of biological reviews that my proposed strategy would generate. A new journal that focussed on biological reviews for specific taxa would help in this regard. Such a journal would also encourage others to produce such biological reviews and promote general accessibility of such reviews amongst potential users. Such a journal should not be limited to hard copy, but, in order to be widely accessible, should also be published electronically and available through the Internet (Janzen 1997).

In order for my proposed strategy, or any similar strategy, to be broadly adopted, it will be necessary for the majority of relevant stakeholders to become involved and reach a consensus view. More specifically, the key players would need to initially agree that: (a) there is a problem worth solving in terms of producing usable taxa-specific reviews of biological information; (b) the solution that will bring the greatest overall benefit is to adopt a standardised approach (like the one proposed here); and (c) a particular solution, from among a number of alternatives, should become the standard. They would then need to agree on a mechanism, such as a new journal dedicated to such reviews, for achieving the broad adoption and implementation of the chosen standard.

The overall task, as I have outlined above, is indeed a daunting one. But the necessary technology for achieving it is now available and so there has probably never before been a better time to start. Furthermore, since the volume of available biological information is ever increasing, it is unlikely that a better time to start will arise some time in the future. It seems to me that the best time to begin the task is now.

## Acknowledgements

This Project has benefitted from the voluntary assistance of a number of people, including G. Geering, M. Pyke, T. Pyke and from discussion with D. Read & A. White. In addition, many helpful

comments and suggestions with regard to earlier versions of this paper were made by L. Dawson, B. Fox, G. Gowing, R. Major and two anonymous referees.

## References

- Allen, G. R., 1989. *Freshwater Fishes of Australia*. T. F. H. Publications: USA.
- Barker, J. and Grigg, G., 1977. *A Field Guide to Australian Frogs*. Rigby: Adelaide, Australia.
- Blakers, M., Davies, S. J. J. E. and Reilly, P. N., 1984. *The Atlas of Australian Birds*. Royal Australasian Ornithologists Union and Melbourne University Press: Melbourne, Australia.
- Cogger, H. G., 1992. *Reptiles & Amphibians of Australia*. Reed: Sydney, Australia.
- Cogger, H. G., Cameron, E. E. and Cogger, H. M., 1983. *Zoological Catalogue of Australia*. Vol. 1. *Amphibia and Reptilia*. Australian Government Publishing Service: Canberra, Australia.
- Coupe, R., 1993. *Australia's Wilderness Heritage*. Vol. 2. Lansdowne Publishing Pty Ltd, Sydney, Australia. 400 pages.
- Cronin, L. (Ed), 1987. *Koala Australia's Endearing Marsupial*. Reed: Sydney, Australia.
- Farr, D. F. and Rossman, A. Y., 1997. Integration of data for biodiversity initiatives. Pp. 475-490 in *Biodiversity II. Understanding and Protecting Our Biological Resources* ed by M. L. Reaka-Kudla, D. E. Wilson and E. O. Wilson. Joseph Henry Press, Washington, DC, USA.
- Fletcher, J. J., 1889. Observations on the oviposition and habits of certain Australian batrachians. *Proc. Linn. Soc. N.S.W.* 4, 357-387.
- Gibbons, P. and Lindenmayer, D. B., 1997. *Conserving Hollow-dependent Fauna in Timber-production Forests*. New South Wales National Parks & Wildlife Service. Environmental Heritage Monograph Series No. 3.
- Hero, J.-M., Littlejohn, M. and Marantelli, G., 1991. *Frogwatch Field Guide to Victorian Frogs*. Victorian Department of Conservation and Environment, Melbourne, Australia.
- Hoser, R. T., 1989. *Australian Reptiles & Frogs*. Pierson & Co., Sydney, Australia. 235 pages.
- Janzen, D. H., 1997. Wildland biodiversity management in the tropics. Pp. 411-431 in *Biodiversity II: Understanding and Protecting Our Biological Resource* ed by M. L. Reaka-Kudla, D. E. Wilson and E. O. Wilson. Joseph Henry Press, Washington, DC, USA.
- Krefft, G., 1863. On the batrachians occurring in the neighbourhood of Sydney, with remarks upon their geographical distribution. *Proc. Zool. Soc. Lond.* 1863: 386-390.
- Lunney, D., Urquhart, C. A. and Reed, P., (Eds) 1990. *Koala Summit. Managing Koalas in New South Wales*. Proceedings of the Koala Summit held at the University of Sydney 7-8 November 1988. New South Wales National Parks & Wildlife Service: Sydney, Australia.
- Lucas, A. H. S. and souef, W. H. D., 1909. *The Animals of Australia. Mammals, reptiles and amphibians*. Whitcombe and Tombs Ltd., Christchurch, New Zealand. 327 pages.
- New South Wales National Parks and Wildlife Service, 1996. Budderoo National Park, Macquarie Pass National Park, Barren Grounds Nature Reserve and Robertson Nature Reserve. Draft Plan of Management. New South Wales National Parks and Wildlife Service, Hurstville, New South Wales, Australia.
- New South Wales National Parks and Wildlife Service, 1996. New South Wales Wildlife Atlas records. New South Wales National Parks and Wildlife Service, Hurstville, New South Wales, Australia.
- Pyke, G. H., 1980. The foraging behaviour of Australian honeyeaters: a review and some comparisons with hummingbirds. *Aust. J. Ecol.* 5: 343-369.
- Research Software Design, 1998. The PAPHYRUS Bibliography System by Dave Goldman. PAPHYRUS Version 7.0.
- State Forests of N.S.W., 1993. *Frog Profiles*. State Forests, Sydney, Australia.
- Strahan, R. (Ed), 1995. *The Mammals of Australia*. Revised Edition. Reed New Holland: Sydney, Australia.
- Tyler, M. J., 1976. *Frogs*. Collins, Sydney, Australia.
- White, A., 1993. Faunal Impact Statement. Proposed development of Telecom site at Roberts Road, Greenacre.

## Appendix 1:

### Part of Basic Information File for Green and Golden Bell Frog *Litoria aurea* dealing with diet of adults in the wild

( Document reference followed by summary of information in document that is relevant to diet of *L. aurea* in the wild)

**Barker, J. and Grigg, G. (1977)**

1. *L. aurea* asserted to be cannibalistic on smaller species and juveniles of its own kind.

**Cogger, H.G. et al. (1983)**

1. *L. aurea* asserted to be a general carnivore.

**Coupe, R. (1993)**

1. Asserted that *L. aurea* is unusual among frogs in that it does not catch insects, but preys instead on other frogs and even small snakes.

**Fletcher, J.J. (1889)**

1. Mr. Masters reported to have observed several *L. aurea* preying on the caterpillars and grasshoppers.

**Frog and Tadpole Study Group (unpublished ms)**

1. *L. aurea* asserted to prey on ground arthropods such as grasshoppers, crickets and cockroaches.
2. It is also asserted that *L. aurea* will eat other frogs and will also cannibalise its own species.

**Hero, J-M. et al. (1991)**

1. It is asserted that *L. aurea* will eat other frogs.

**Hoser, R.T. (1989)**

1. *L. aurea* described as a voracious canibalistic frog.

**Kreff, G. (1863)**

1. It is asserted that *L. aurea* feeds upon almost any frog, no matter what, as long as it can be swallowed.
2. It is also asserted that *L. aurea* will devour lizards and large cockroaches and that, if hungry, " nothing appears to come amiss to them".

**Lucas, A.H.S. and Le Souef, W.H.D. (1909)**

1. It is asserted that at night, if the ground is wet with rain or dew, *L. aurea* will wander over it seeking slugs, worms, insects, etc.
2. It is also asserted that in the daytime *L. aurea* keep on the margins of pools or in water, taking advantage of any opportunity to capture flies or mosquitoes.

**State Forests (1993)**

1. It is asserted that *L. aurea* eats a wide variety of invertebrates including ants, beetles and centipedes.
2. It is also asserted that *L. aurea* will feed on anything small enough to handle, especially other frogs.

**White, A. (1993)**

1. It is asserted that *L. aurea* includes other frogs in its diet.

## Appendix 2:

### Review of diet of adult *Litoria aurea* in the wild

1. There is only one reported observation of dietary items for adult *L. aurea* in the wild, and this a second-hand report of frogs feeding on caterpillars and grasshoppers (see Fletcher 1889; Appendix 1).
2. There is apparent general agreement amongst authors that *L. aurea* is a generalist carnivore, feeding on a wide variety of animal prey, including members of its own species, other frog species, ground-dwelling insects and other ground-living invertebrates (Appendix 1; Table 1).

3. Some authors assert that *L. aurea* will occasionally eat small reptiles and flying insects such as flies and mosquitoes.
4. So far there have apparently been no studies which provide information in terms of:
  - the relative importance of different dietary items in the diets of adult *L. aurea* in the wild and how this might vary with factors such as location, time of year, age/sex of individual etc
  - the nature and extent of any selectivity by adult *L. aurea* in choosing prey items to attack